COMPUTATIONAL ANALYSIS OF HEAT TRANSFER RATE USING THERMAL RESPONSE FACTOR METHOD

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SUPERVISOR'S DECLARATION

We hereby declare that we have checked this project and in our opinion this project is satisfactory in terms of scope and quality for the award of the degree of Bachelor of Mechanical Engineering.

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STUDENT'S DECLARATION

I hereby declare that the work in this project is my own except for quotations and summaries which have been duly acknowledged. The project has not been accepted for any degree and is not concurrently submitted for award of other degree.

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ABSTRACT

A study of heat transfer rates through a wall of air conditioned buildings is presented in this thesis. The transfer of energy as heat is always from the higher temperature to lower temperature and the heat transfer stops when the two medium reach the same temperature or in equilibrium. The Microsoft Visual C++ software is used to analyze the heat transfer rate into wall building by using Thermal Response Factor method. The parameters and thermal physical properties of the material are obtained in the analysis. The local weather data for Kuantan City has been used for all the result presented, the data for temperature starting from January until December in year 2008. The temperature used in this project was the typical temperature for six days in one year. Each typical temperature represent for two month as January and February month. The parameters and thermal physical properties used were wall thickness, wall insulation, wind velocity and density of material. The comparison between result from ASHRAE Book and computer programming showed the percentage error is around about 36.98%. Thermal Response Factor method using Visual C++ software can be used to determine the heat transfer rate through a wall building which is has the differences of thermal physical properties.

ABSTRAK

Projek ini ialah kajian terhadap kadar pemindahan haba ke dalam sesuatu dinding bangunan yang berhawa dingin. Pemindahan haba ke dalam sesuatu bangunan berlaku daripada suhu yang lebih tinggi kepada suhu yang lebih rendah, walaubagaimanapun kadar pemindahan haba ini akan berhenti apabila keaadaan suhu adalah sama atau lebih dikenali mencapai satu tahap yang seimbang. Perisian Visual C++ digunakan dengan kaedah Sambutan Terma untuk mencari kadar pengaliran haba ke dalam permukaan bangunan. Keadaan parameter dan sifat terma fizikal bagi sesuatu bahan diambil kira di dalam kajian ini. Data suhu bagi bandar Kuantan daripada bulan Januari hingga Disember bagi tahun 2008 digunakan di dalam projek ini. Suhu harian yang digunakan di dalam projek ini ialah suhu 6 hari tipikal di dalam setahun. Setiap satu suhu tipikal ini mewakili 2 bulan seperti satu hari tipikal mewakili bulan Januari dan Februari. Parameter dan sifat terma fizikal yang digunakan di dalam projek ini adalah ketebalan dinding bangunan, penebatan pada bangunan , kelajuan angin dan ketumpatan bahan. Peratusan perbandingan di antara keputusan daripada buku ASHRAE dengan program komputer ialah sebanyak 36.98%. Ini menunjukkan kaedah Sambutan Terma boleh digunakan untuk mecari kadar haba pada sesuatu dinding bangunan yang mana mempunyai sifat terma fizikal yang berbeza.

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LIST OF SYMBOLS

A	Area
Bi	Biot number
C_p	Constant pressure specific heat
crz,cry	Common ratio
Fo	Fourier number
h	Convection heat transfer coefficients
k	Thermal conductivity
Nu	Nusselt number
P	Period of time
Pr	Prandtl number
Q	Heat transfer rate
q	Heat flux
R	Resistance conductivity
Re_x	Reynolds number
TRF	Thermal Response Factor
t_o	Outside temperature
X,Y,Z	Thermal Response Factor
x	Wall thickness
	Thermal diffusivity
Δt	Change of temperature
Δx	Change of distance
ρ	Density of material

LIST OF ABBREVIATIONS

ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
TRF	Thermal Response Factor
CTF	Conduction Transfer Functions
ZTF	Z-Transfer Function
SG	Specific Gravity
RD	Relative Density

CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

The first law of thermodynamics states that the energy of a closed system is conserved. Therefore, to change the energy of a system, energy must be transferred to or from the system. Heat and work are the only two mechanisms by which energy can be transferred to or from a control mass. Heat is the transfer of energy caused by the temperature difference. [Yunus, 2006]

Heat transfer is a path function (process quantity), as opposed to a point function (state quantity). Heat flows between systems that are not in thermal equilibrium with each other; it spontaneously flows from the areas of high temperature to areas of low temperature. When two bodies of different temperature come into thermal contact, they will exchange internal energy until their temperatures are equalized; that is, until they reach thermal equilibrium. [Yunus, 2006]

The hot is used as a relative term to compare the object's temperature to that of the surroundings. The term heat is used to describe the flow of energy. In the absence of work interactions, the heat that is transferred to an object ends up getting stored in the object in the form of internal energy. [Yunus, 2006]

1.2 PROBLEM STATEMENT

Heat transfer is commonly encountered in engineering systems and other aspects of life, and one does not need to go very far to see some application areas o heat transfer. In fact, one does not need to go anywhere. The human body is constantly rejecting heat to its surroundings, and human comfort is closely tied to rate of this heat rejection. From this problem, we try to control this heat transfer rate by adjusting our clothing to the environment condition.

Malaysia is a tropical country. Tropical country is a hot and wet country. Nowadays maximum temperature at Malaysia is about 33^{o}C where this situation gives uncomfortable condition to peoples especially in a closed space with a large number of peoples. This situation makes the indoor space become hot and the peoples inside feel not comfortable with this condition. Therefore, the analysis of heat transfer should be done to decreases the heat to provide comfort the occupants.

1.3 OBJECTIVE OF PROJECT

The objectives of the project are:

i. To analyze the heat transfers rate through the wall based on the thermal physical properties.

ii. To develop the computer programming using C++ software.

1.4 SCOPE OF PROJECT

The scopes of this project are:

i. To develop the computer programming using the Microsoft Visual C++ software.

ii. To analyze the effect of heat insulator position in the wall.

iii. To analyze the heat transfer rate through a wall based on thermal physical properties.

iv. To find the heat transfer rate (heat flux) through a wall based on heat balance equation.

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

Study of literature or scientific studies on the heat transfer rate through a wall building are built to go deep into the concepts and find the declaration related to feature of this project. This study will be more to discuss about the scope projects that stated before.

2.2 HEAT TRANSFER MECHANISMS

A thermodynamic analysis is concerned with the amount of heat transfer as a system undergoes a process from one equilibrium state to another. The transfer of energy is always from the higher temperature medium to the lower temperature medium, and heat transfer will stops when the two medium reach the same temperature.

Heat can be transferred in three different modes as conduction, convection and radiation. All modes of heat transfer require the existence of a temperature different, and all modes are from the high temperature medium to a lower temperature medium.

Unsteady heat transfer for a solid wall is one way to find the changes in temperature against time between the wall nodes. The inner nodes distinction given the same distance between each other's and the temperature outside and temperature inside must note first. From here, the heat conduction equation and heat convection equation will be used to find the heat transfer rate to wall building. [Yunus, 2006]

2.2.1 CONDUCTION

Conduction is the transfer of heat by direct contact of particles of matter. The transfer of energy could be primarily by elastic impact as in fluids or by free electron diffusion as predominant in metals or phonon vibration as predominant in insulators. In other words, heat is transferred by conduction when adjacent atoms vibrate against one another, or as electrons move from atom to atom. Conduction is greater in solids, where atoms are in constant contact. In liquids (except liquid metals) and gases, the molecules are usually further apart, giving a lower chance of molecules colliding and passing on thermal energy. [Yunus, 2006]

Heat conduction is directly analogous to diffusion of particles into a fluid, in the situation where there are no fluid currents. This type of heat diffusion differs from mass diffusion in behavior, only in as much as it can occur in solids, whereas mass diffusion is mostly limited to fluids. [Yunus, 2006]

In the heat transfer by conduction calculation, the Crank-Nicholson method in one dimension will be used, the Crank-Nicholson methods is numbering method that requiring to find every inner node in the wall.

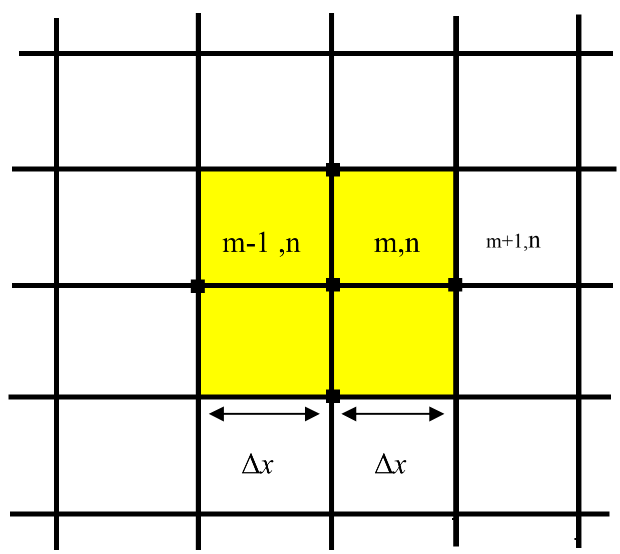

Figure 2.1: The inside node points in the wall, heat transfer by conduction

The increasing of this value is Δx in the direction x. Figure 2.1 shows the inner node in the wall. Let, a small letter m denotes as a direction of ***x*** and the lowercase n as a direction of y (Holman, 1992). With assume the properties of material is constant, then the equation of the heat flow in matter is

$$k\left(\frac{}{} + \frac{}{}\right) = \quad \frac{}{} \tag{2.1}$$

but heat flow in the wall is in one dimension only, so

$$\frac{}{} = 0 \tag{2.2}$$

the above equation becomes

$$k\left(\frac{}{}\right) = \quad \frac{}{} \tag{2.3}$$

and simplify to

$$\frac{}{} = \quad \frac{}{} \tag{2.4}$$

with,

$$= k\,/ \tag{2.5}$$

= thermal diffusivity (m^2/s)

k = thermal conduction (W/mK)

= density of material (kg/m^3)

= constant pressure specific heat (kJ/kg.K)

When solving the equation above, the equation becomes

$$T'_m = — (T_{m+1} + T_{m-1}) + (1 - —)\, T_m \tag{2.6}$$

$$= \frac{(\Delta \quad)}{\Delta} \geq 2 \text{ (for one dimension case)}$$

Clear here from equation above if M is less than 2, the situation is not suitable which the coefficient is of T_m will become negative. So the higher value of T_m, the value of T'_m will be smaller which is not correct. That why the value of M greater or equal to 2.

2.2.2 CONVECTION

Convection is the mode of energy transfer between a solid surface and the adjacent liquid or gas that is in motion, and it involves the combined effects of conduction and fluid motion. The faster the fluid motion, the greater the convection heat transfers. In the absence of any bulk fluid motion, heat transfer between a solid surface and the adjacent fluid is by pure conduction. The presence of bulk motion of the fluid enhances the heat transfer between the solid surface and the fluid, but it also complicates the determination of heat transfer rates. [Yunus, 2006]

Apart from the heat transfer in each node through walls, heat transfer also happened at convection boundary on the surface of the walls outside and inside. It is dependent to the temperature inside and outside walls including the convection heat transfer coefficient, *h* ($W/m^2.K$) (Holman, 1992). Figure 2.2 show the heat transfer at convection boundary.

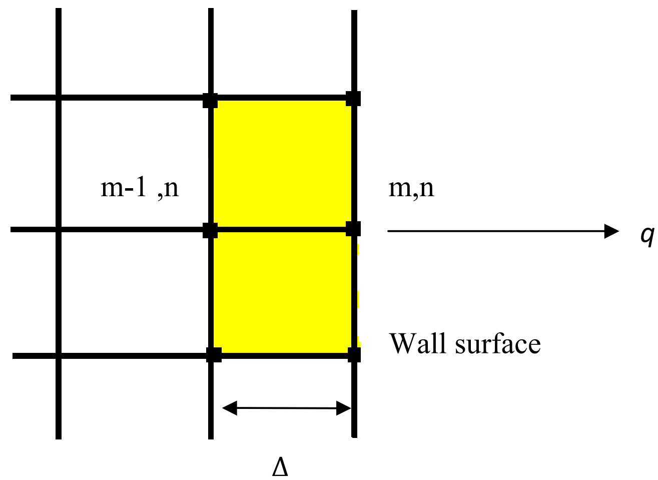

Figure 2.2: Node points at wall surface, heat transfer by convection

The solution for this problem is based on the equation 2.7 but involve the convection heat transfer coefficient, *h* ($W/m^2.K$), and the ambient temperature outside and inside of the wall. The relationship heat transfer by convection with one-dimensional case is written as follows

$$T'_m = - (2 \quad _{\infty} + [\quad -2(\quad +1)]\ T_m) \tag{2.7}$$

with,

$$= \frac{\Delta}{\quad} \tag{2.8}$$

$$= \frac{(\Delta \quad)}{\Delta} \tag{2.9}$$

= Biot number

h= convection heat transfer coefficient,($W/m^2.K$)

k = thermal conduction, (W/mK)

Δ = change of wall thickness (m)

Δ = change of time (s)

Note that the selection of the parameters *M* for the node on the border of heat convection must be suitability requirements by requiring,

$$M \geq 2(\quad + 1) \tag{2.10}$$

After increasing the distance Δx is selected, the values mentioned above for the M will limited the value Δt. A higher value for *M* may be selected. This means a the value of Δt will small and effect the value of Δx, from this situation, the distance and time period used in calculation is long but it will give a more precise result.

Conversely, if the value *M* of smaller (although the value had more than limited value) this means the value of Δt to be something big for the Δx, from this, the distance will be decreasing and the period time that used in the calculation also decreasing but the decision precise (Incropera, 1996). It is clear here that the selection must be made the high accuracy of the calculation period or which less in this problem will depend on the situation.

The important things in the heat transfer by convection is convection heat transfer coefficients, h where it is dependent to the Reynolds Number, R .That means thet flow of heat transfer may occur as laminar or turbulent depending on the volume flow rate.

From the method above, the heat transfer rate into the wall building can be determine from the equation below,

$$= h \quad \Delta \tag{2.11}$$

where,

= heat transfer, (kJ)

h = convection heat transfer coefficients (W/m^{2}K)

= area (m^2)

Δ = temperature different (K)

2.3 THERMAL PHYSICAL PROPERTIES

2.3.1 THERMAL CONDUCTIVITY, *k* (W/m.K)

Thermal conductivity value is a measure of absorbed heat value and numbered heat thermal conductivity shows how the rate will flow in a material. Thermal conduction in one solid material may as one of heat flux change according to the direction and position in the materials. (Mohd Zainal, 1991)

Solid material can be divided into two groups, the metal and not metal, where there is a very big cliff on the thermal conductivity value. Table 2.1 and table 2.2 show some of the important material that usually used in industry.

The high value of high conductivity in the material is caused by spotlessness order that the crystal structure. The order of molecular lead will affect the heat transfer more quite. Metals such as copper is a good electricity conductor and also with a good heat stream

Table 2.1: Thermal properties of Metal (Holman, 1992)

Material	**(kg/m^3)**	C_p**(kJ/kg.K)**	**k (W/m.K)**
Aluminum	2707	896	204
Iron	789	452	72.7
Tin	7304	227	64
Copper	8954	385	111
Magnum	1746	1013	171
Molybdenum	8906	446	90
Zinc	7144	384	112
Lead	11370	130	34.6

Table 2.2: Thermal properties of Non-Metal (Holman, 1992)

Material	**(kg/m^3)**	C_p**(kJ/kg.K)**	**k (W/m.K)**
Bakelite	1273	1590	0.0232
concrete	1906	879	0.049
Plaster	1442	837	0.0413
Asbestoses	577	816	0.151
Glass	200	670	0.00398
Cotton	80.1	1298	0.0589

Non-metallic materials are very different because it does not have a structure that stacks neatly. Thus, the flow of heat transfer between molecules is limited value and the value for thermal conductivity is lower. The small hole in the material filled in by the air stream so will affect the heat transfer because gas is a bad heat conductor.

This is because the molecule gases in that position is more quite separate and the heat transfer is depend on the collision between molecules. (Mohd Zainal, 1991)